Amherst Center for Fundamental Interactions
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Exploding Primordial Black Holes

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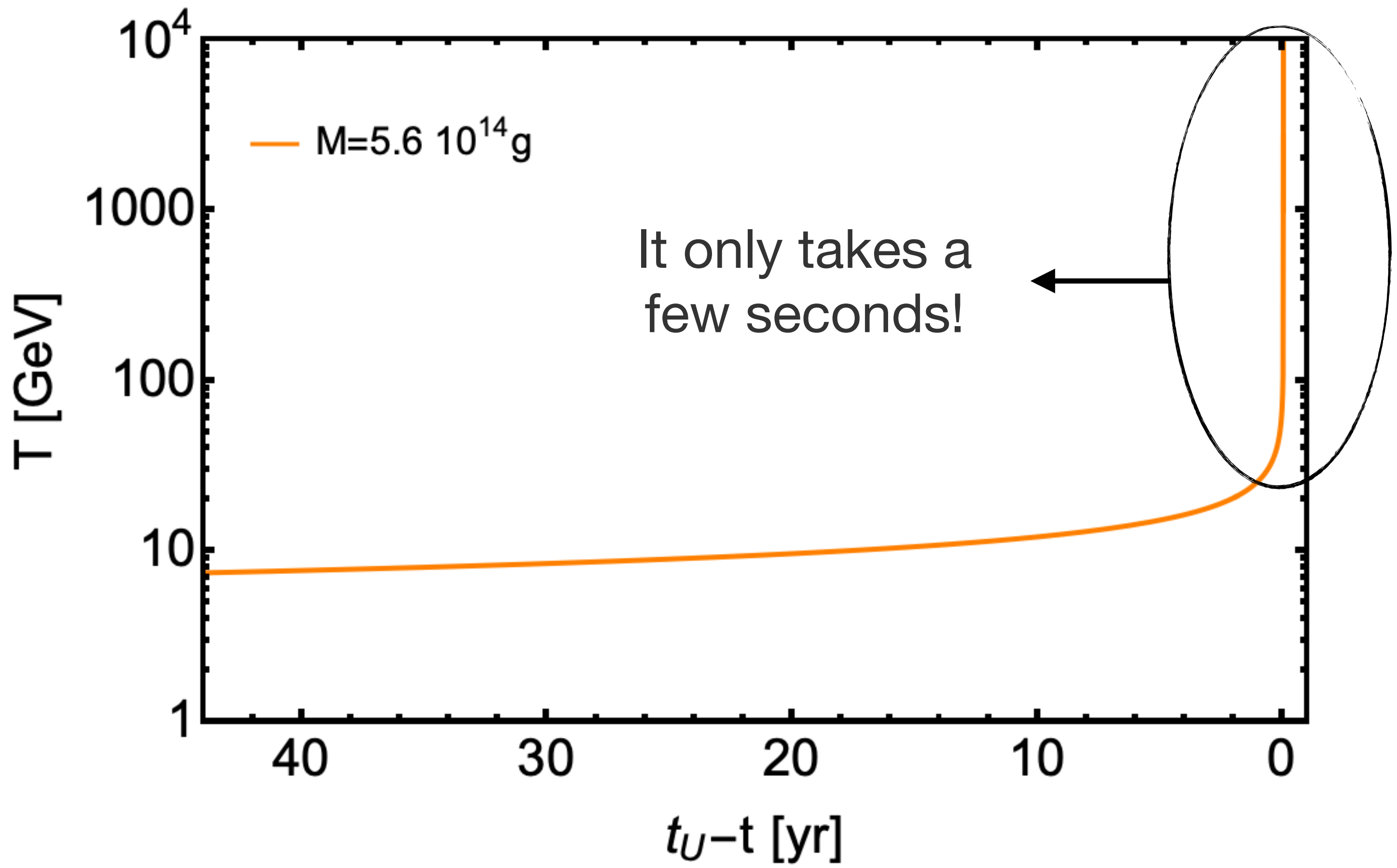
Exploding PBHs

Black hole explosions?
S.W. Hawking. *Nature* 248, 30-31 (1974)



Current HAWC limit is $\dot{n} < 3400 \text{ pc}^{-3} \text{ yr}^{-1}$

HAWC Collaboration. *JCAP* 04 (2020) 026

Unprecedented observation!

Experimental evidence for **Hawking radiation**

BSM physics
(dark sector secluded from visible sector?)

T.N Ukwatta et al. *Astropart.Phys.* 80 (2016) 90-114
M.J. Baker et al. *SciPost Phys.* 12 (2022) 150
M.J. Baker et al. *JHEP* 01 (2023) 063

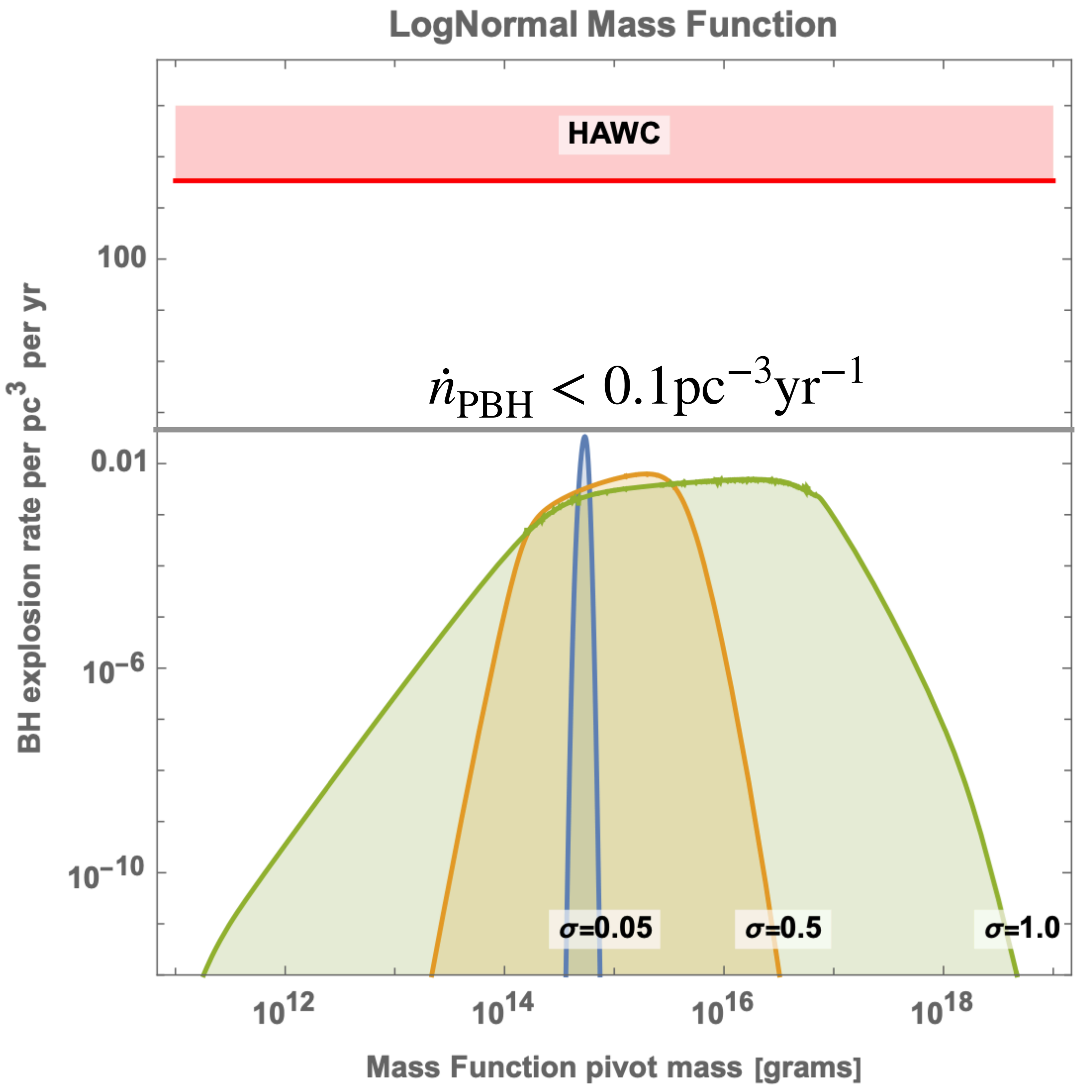
Quantum gravity
(physics close to Planck scale)

B. Lehmann et al. *JCAP* 10 (2019) 046

How to enhance the (local) burst rate?

Mass function? Most favorable scenario is a monochromatic mass function…

X. Boluna et al. *JCAP* 04 (2024) 024



For log-normal:

$$\psi(M, M_*, \sigma) = \frac{\exp\left(-\frac{\log(M/M_*)^2}{2\sigma^2}\right)}{\sqrt{2\pi}\sigma M}$$

$$\dot{n}_{\rm PBH} \simeq \frac{1.2 \times 10^{-3}\ {\rm pc}^{-3}{\rm yr}^{-1}}{\sigma}$$

We want to maximize burst rate

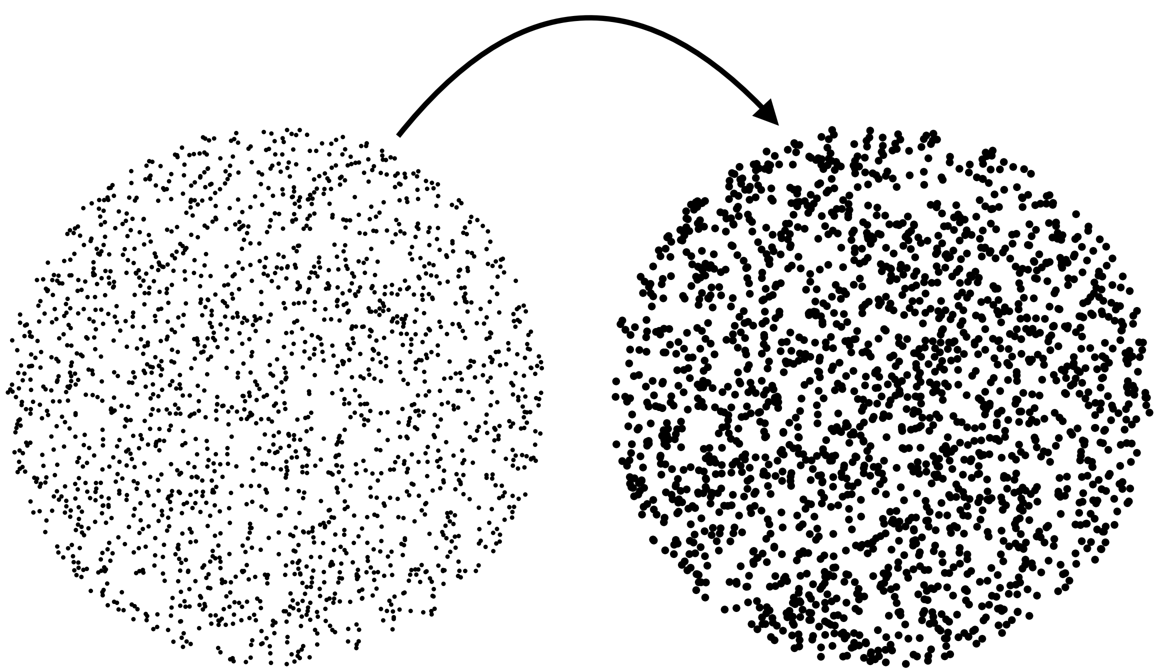
$$\dot{n}_{\rm PBH} = \rho_{\rm DM} \frac{\psi(M_U)}{3t_U}$$

How to enhance the (local) burst rate?

The key object is the number density $N_{\rm PBH} = f_{\rm PBH}\dfrac{\rho_{\rm DM}}{M_{\rm PBH}}$

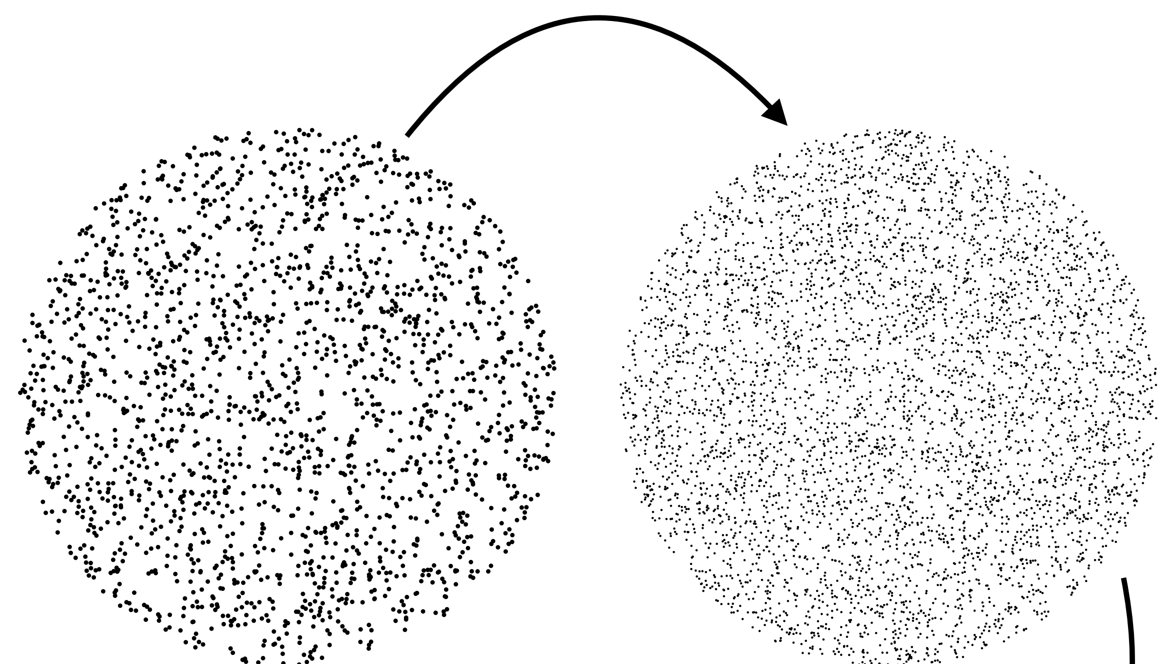
Same number density

Larger DM fraction



Larger number density

Same DM fraction

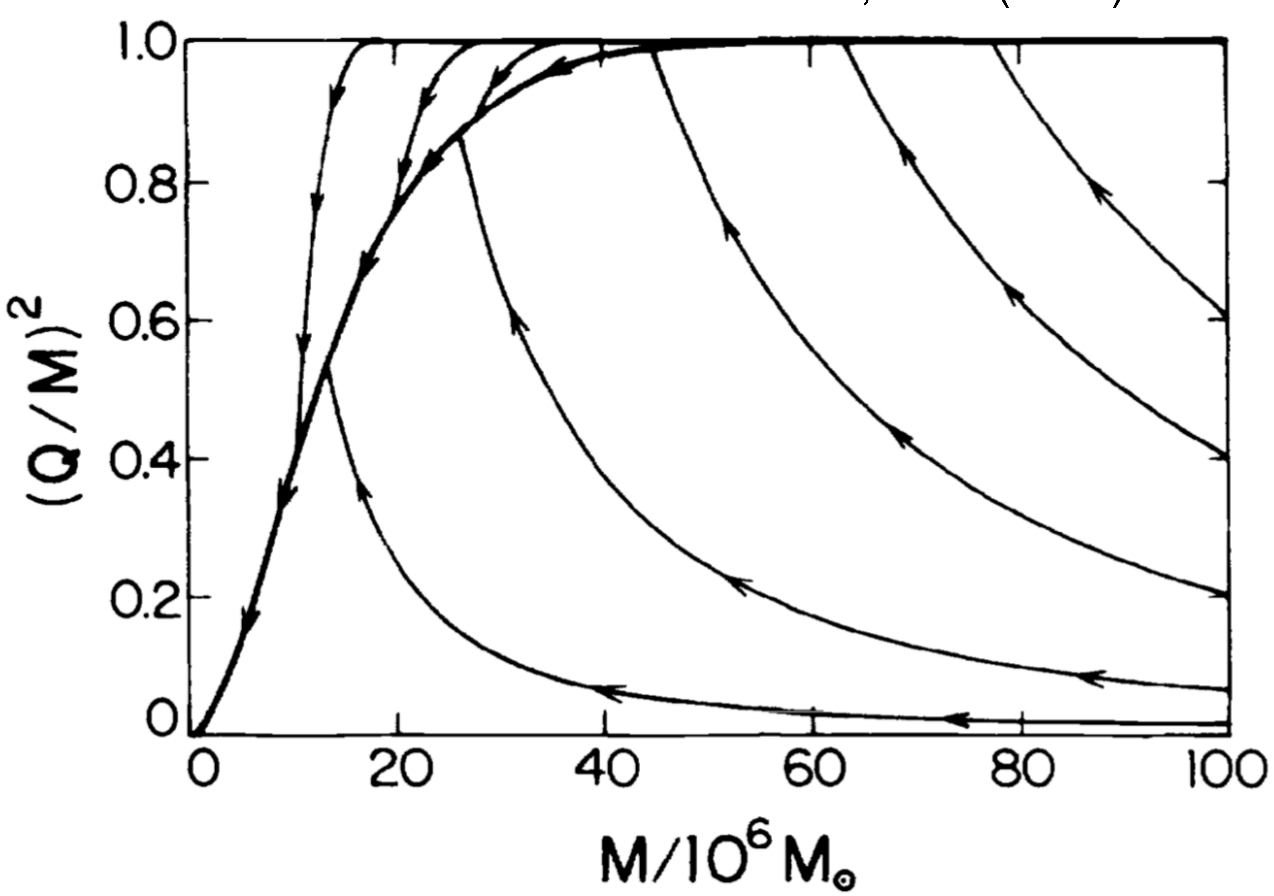


More PBHs → more bursts!

How to enhance the burst rate?
(or how to produce lighter BHs?)

Beyond SM and Schwarzschild black holes:

W. A. Hiscock et al. *PRD* 41, 1142 (1990)



Discharge due to Schwinger effect.

$$\frac{d\Gamma}{dV} = \frac{e^2}{4\pi^3}\frac{Q^2}{r^4}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left(\frac{-\pi n m^2 r^2}{eQ}\right)$$

$$T_{RN}(Q^* = Q/M \to 1) \ll T_{Sch}$$

- ✔ γ emission suppressed, so weakens contribution to indirect bounds
- ✘ Accretion will neutralize BH in astrophysical setup
- ✘ PBHs are too massive (no explosions)
- ✘ Timescales are too long!

Beyond SM and Schwarzschild black holes

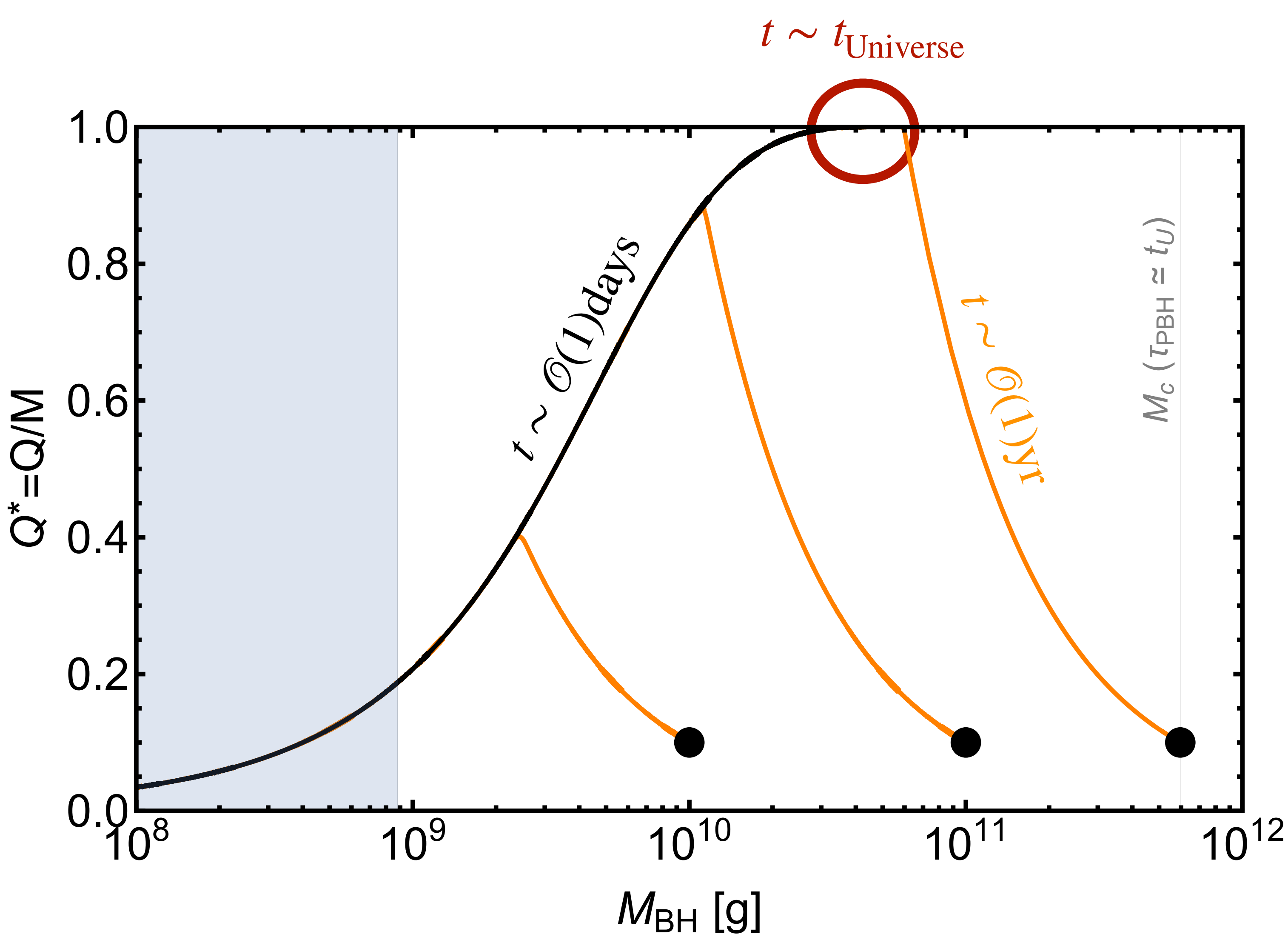
Y. Bai et al. *PRD* 101 (2020) 5, 055006

Introduce massive dark electron.

Viable PeBH formation mechanism.

$\Longrightarrow$

- Schwinger effect (fast)
- Light PBHs
- PBH spends most of its time being extremal



$m_{de} = 10^7\text{GeV}$

$e_d/e_{SM} = 10^{-9}$

Can be realized in large portion of parameter space for the dark model*.

*We assume $Q^* = 0.1$ at formation. Parameter space is more constrained for lower initial values.

Indirect bounds

PBHs explode today

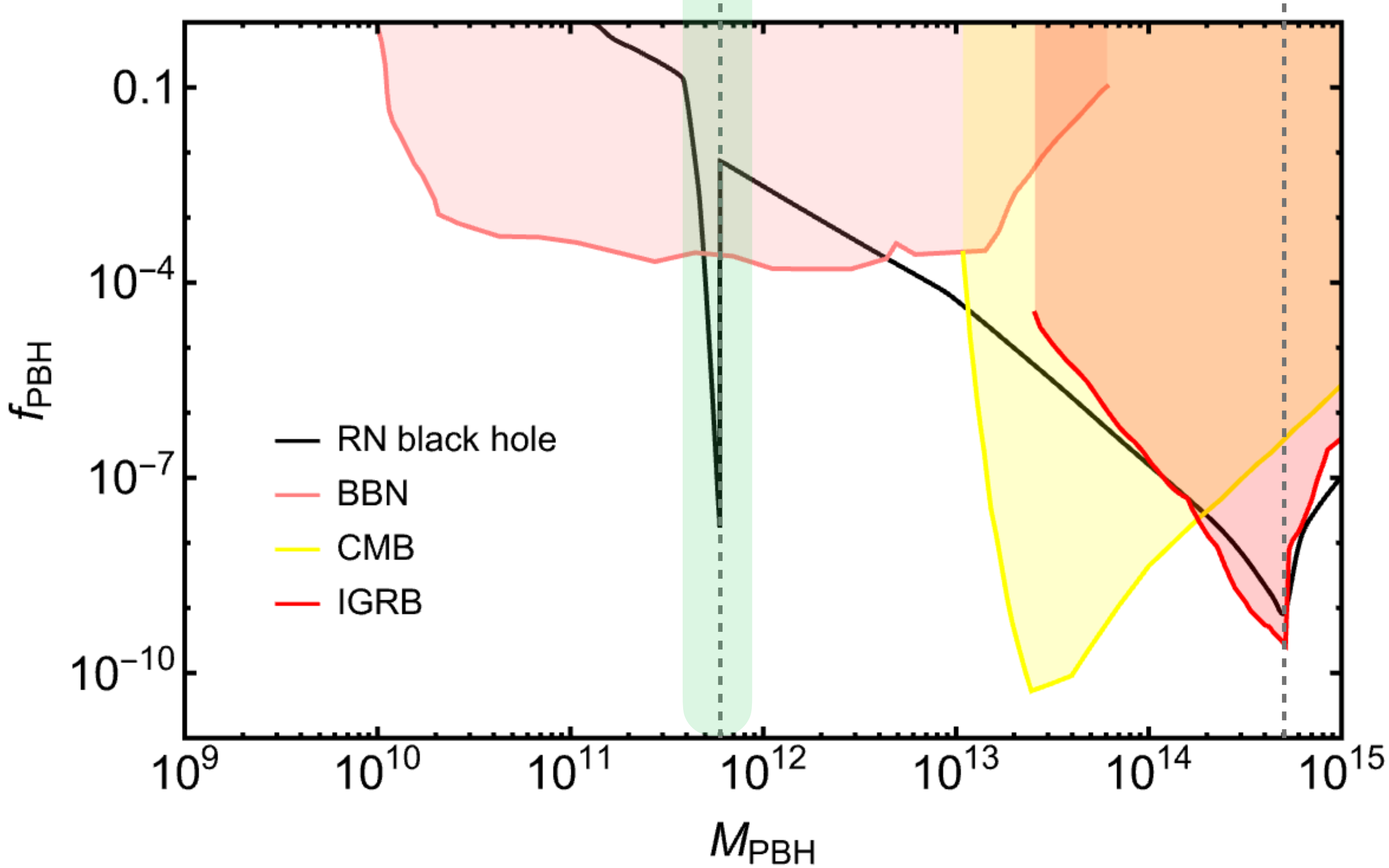
PBHs that have already evaporated

PBHs in quasi-extremal state

PBHs still evaporating (have not reached quasi-extremality)

⇓

Usual bounds on f_{PBH} for Schwarzschild BHs

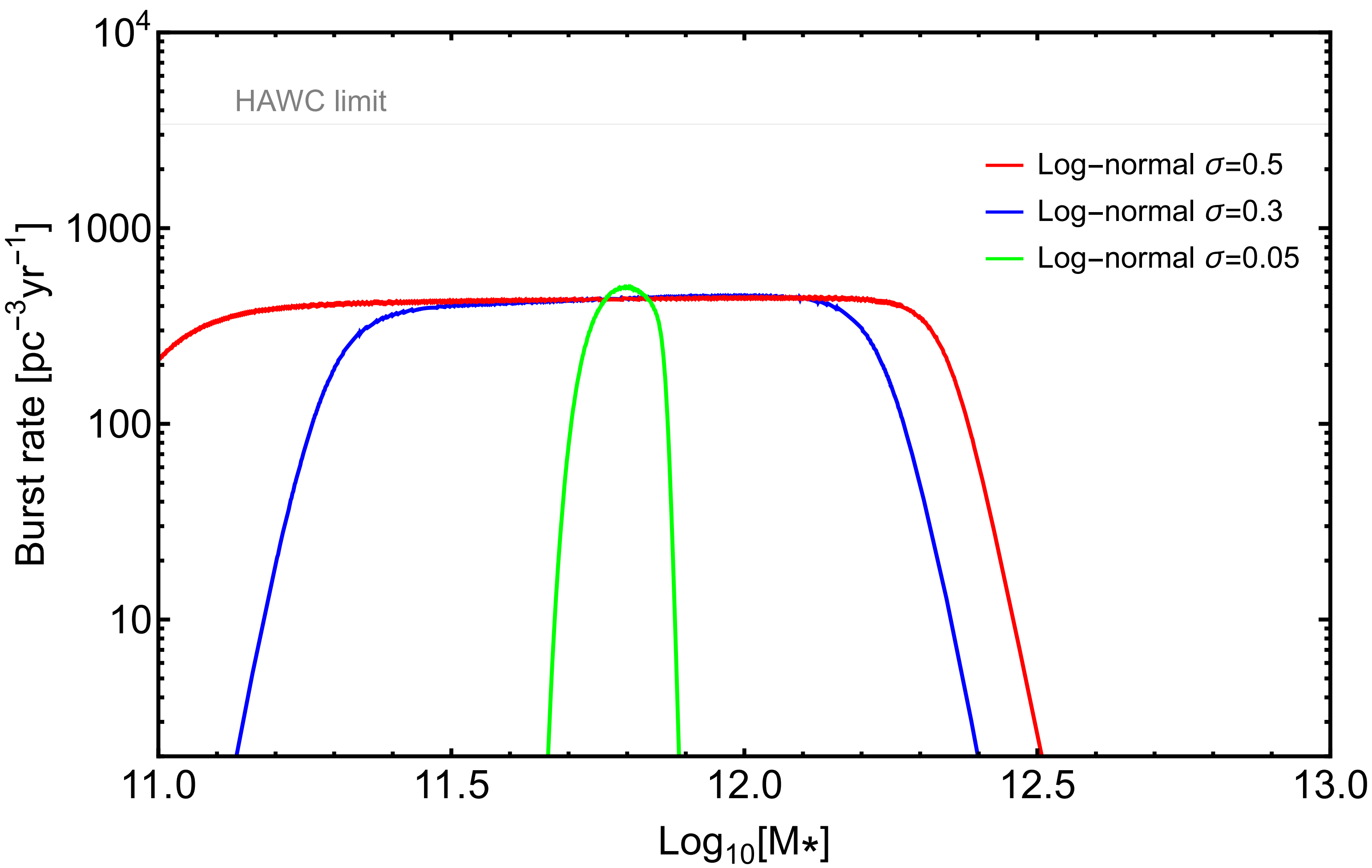


Direct bounds (burst rate)

The burst rate is significantly enhanced!

Maximal burst rate in standard scenario is $\dot{n}_{\rm PBH} \lesssim 0.1 {\rm pc}^{-3}{\rm yr}^{-1}$ $\Longrightarrow$ Enhanced by more than 4 orders of magnitude

X. Boluna et al. *JCAP* 04 (2024) 024



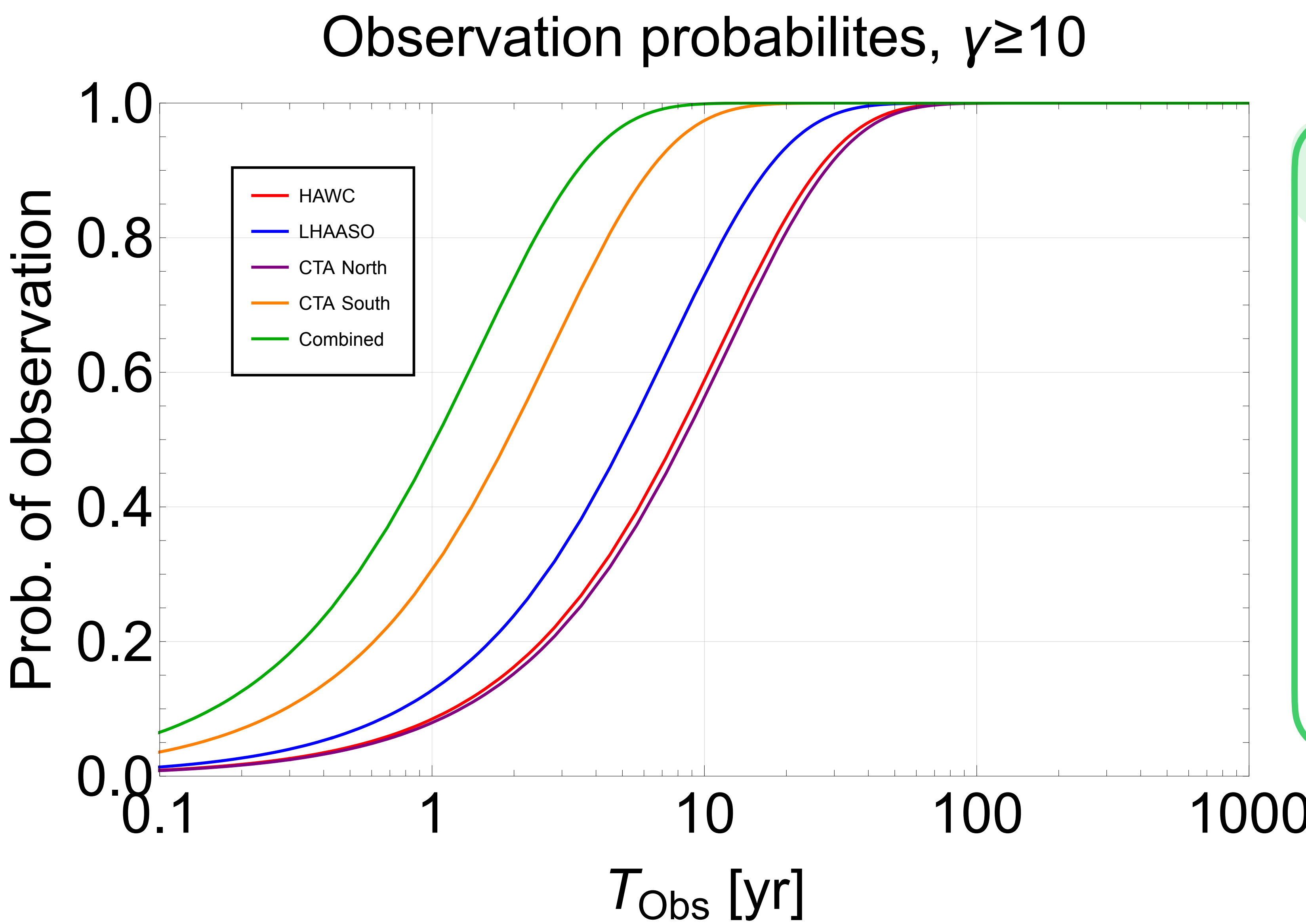
$m_{de} = 10^7 {\rm GeV}$

$e_d / e_{SM} = 10^{-9}$

Log-normal mass distribution

$$\psi(M, M_*, \sigma) = \frac{\exp\left(-\frac{\log(M/M_*)^2}{2\sigma^2}\right)}{\sqrt{2\pi}\sigma M}$$

Beyond SM and Schwarzschild black holes



ASSUMPTIONS:

$m_{de} = 10^7 \mathrm{GeV}$ $e_d/e_{SM} = 10^{-9}$

$Q_{\mathrm{i}}^* = 0.1$

Log-normal mass distribution

$\dot{n}_{\mathrm{PBH}} = 400 \mathrm{pc}^{-3} \mathrm{yr}^{-1}$

Conclusions

The observation of an exploding black hole would be an unprecedented event and would offer insights on fundamental physics topics.

We have the technological capacity (HAWC, LHAASO, CTA) to observe such event. However, there are very stringent constraints on the population of exploding BHs.

EXTREMAL BHs

A window of opportunity opens when considering extremal black holes.

We provided the first explicit scenario that yields enhanced burst rates (by more than 4 orders of magnitude!) and good chances of seeing an exploding BH.

Alternative models (extra dimensions, magnetic monopoles etc.) could also lead to interesting scenarios, further analysis is required.